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PLATE IV.

THE DISC FOR THE 74-INCH MIRROR.

(Above) The grinding tool on the concave surface.

(Below) The tool raised, the rough grinding completed. When cast the disc was 76¾ inches in diameter and about 14 inches thick. Photographed at Newcastle in December, 1933.

Journal of the Royal Astronomical Society of Canada, 1934.

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THE 74-INCH TELESCOPE OF THE DAVID DUNLAP OBSERVATORY

By R. K. Young

(President's Annual Address, January 16, 1934)
(With plate IV)

THE buildings and preliminary equipment for the David Dunlap Observatory are nearing completion. The Administration Building is finished. It will provide space for offices, for library, and for laboratories required in the measurement of the photographic plates and in subsidiary investigations. The copper-covered steel dome and circular building for the large telescope has been erected, although considerable work still remains to be done. The mounting for the telescope is in place. The large mirror is at present in England being ground (see Plate IV), and is expected to be ready within a year.

The two buildings stand out clearly on the sky line to the east as one travels north on Yonge St. between Thornhill and Richmond Hill. The Administration Building is built of stone along classical lines, and does great credit to the architects. The building which houses the great telescope does not lend itself to the same architectural possibilities, but nevertheless it harmonizes well with the Administration Building. The observatory stands on the highest ground in that vicinity, the ground floor of the great dome being about 800 feet above sea level. It is in the midst of an estate of 179 acres. This amount of land seems to many unnecessarily large, but there is a very important reason for having it. The large telescope will be used almost exclusively for photography and must not be interfered

with by any extraneous light. It is therefore essential to prevent too many buildings and houses being erected in close proximity to the observatory. The small village of Richmond Hill, about one mile to the north-west, offers an objection to the site; but it is not serious because fully three-fourths of the work will be done with the telescope pointing south of the zenith and the lights from the village will not shine directly into the dome.

The land around the observatory is at present quite open, with a few trees and shrubs scattered here and there. It would be much better from an astronomical point of view if the land were more heavily wooded. It is intended to make the land into a park, to be known as the David Dunlap Park, and is very desirable to plant trees over the area as soon as possible. The reason for having the ground covered with a growth of trees is to shield it from the sun on the warm summer days. On an open plain the ground becomes quite hot during the day; and when, at sunset, this heat is given off again, the warm air flowing upwards creates an unsteady atmosphere which interferes with the use of the telescope. The trees and vegetation absorb a great part of the sun's heat so that a steady state of the atmosphere is reached much more quickly. It is planned to have the site developed under the superintendence of the Department of Forestry of the University. Although the project of the observatory was started five years ago, this part of the scheme has been delayed by circumstances beyond our control. It should be carried out without delay.

Most of you however when you think of the observatory have in mind chiefly the large telescope which will be housed in the "Big Dome", and it is of it that I shall speak this evening. There will be smaller telescopes in the domes on the Administration Building capable of doing a great deal of good work. The small dome to the south will house the 19-inch reflector made some time ago in the University. The central dome will contain a 10-inch or a 12-inch visual refractor, and in the north dome will be mounted a photographic refractor. These subsidiary telescopes will be especially useful in an observatory so closely associated with instruction in the University.

The principle of the telescope was discovered about the year

1608. The first famous telescope of Galileo was one and five-eighths inches in diameter and about twenty inches long. At that time the making of a telescope would not have been considered an engineering problem. The principles of the telescope are the same now as then, but the increase in size from an inch or so to several feet makes all the difference. There is probably no instrument which necessitates the combination of technical and engineering skill to such an extent if the final product is to be satisfactory.

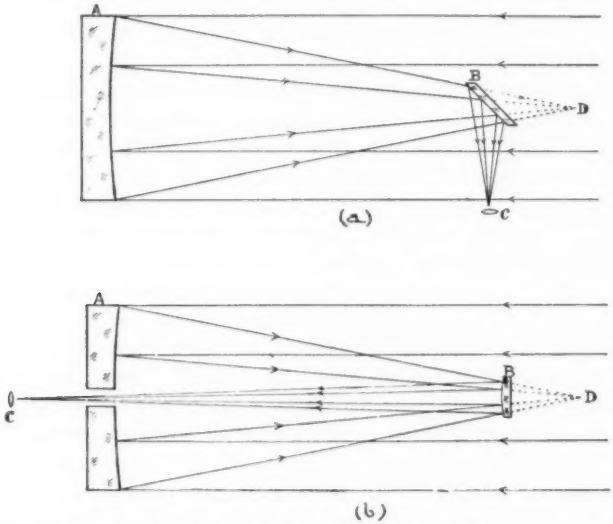


FIG. 1. Principle of the reflecting telescope; (a) Newtonian form, (b) Cassegrainian form.

The principles upon which a reflecting telescope is based are illustrated in Figs. 1*a* and 1*b*. In *a* the Newtonian form is shown, so-called after Sir Isaac Newton, its inventor. The light from a distant source is imagined coming from the right in a sensibly parallel beam which strikes the mirror *A*. The front surface of *A* is made hollow, being a paraboloid of revolution. This type of surface reflects the rays of all colours to the same point *D*, called the prime focus. In the Newtonian type of telescope a plane mirror is placed

at *B* in the path of the converging beam and inclined at 45° to the axis, so that the beam is bent through a right angle and the focus is near *C*, where it may be examined with a magnifying glass or eyepiece.

In *b* we have the Cassegrain form of the telescope. The light which is reflected from the silvered glass mirror *A* in this case falls on a convex mirror *B* before it reaches the focus, and if the convex mirror is a portion of an hyperboloid of revolution, all the rays will be reflected back to a point near *C*. It is necessary in this case to have a hole in the centre of the mirror *A* to allow the light to reach the focus *C*.

These schemes look so simple that it is not at first apparent why it should be a difficult problem to make a telescope several feet in diameter. In the first place, however, the mirror *A* must be truly parabolic in shape with departures of the order of one-millionth of an inch. It must be very rigid in order to resist flexure, and consequently heavy. The best material yet discovered from which to make a mirror is glass. In the 74-inch instrument the mirror will consist of a solid disc about thirteen inches thick weighing about 5,000 pounds and made of pyrex. The advantages of pyrex are that it has a small temperature coefficient of thermal expansion and is a stable glass. The disc has been cast at the Corning Glass Works, Corning, N.Y., and is now in England at the optical shops of Sir Howard Grubb, Parsons and Company, at Newcastle-on-Tyne, where it will be ground and finished.

In the second place the telescope must be capable of being pointed towards any object without loss of time, and must be driven by some mechanism to follow the object continuously as it moves across the sky. It must not only keep the object in the field of view but must hold the image stationary. A drift of the image of a thousandth of an inch during the course of an exposure when the telescope is being used for photography would seriously affect the definition of the picture. The engineering difficulties confronting the telescope maker in thus keeping the tube so accurtaely pointed are about equivalent to keeping a gun pointed on a target an inch in diameter at a range of twenty miles while the target is moving at the rate of five feet per second.

The mechanical parts which support the mirrors are usually spoken of as the "mounting." The whole instrument must be sheltered by a building which can be opened to permit a view in any direction and provide means of convenient access for the observer to any part of the telescope.

The technique of telescope making has evolved gradually. Experience has had to point the way for advances and, as in other lines of engineering production, the changes are suggested by the weaknesses of former models. There are comparatively few firms that have sufficiently large machinery to handle the massive castings which support the optical parts, and, when we combine with this the fact that the number of firms which have had experience in telescope building is very small also, we see that the project could be tendered for by a very restricted few. In 1927, when Mrs. D. A. Dunlap expressed her willingness to provide the means to construct a large telescope, tentative specifications were drawn up and in June of 1928 sent to four firms: the Carl Zeiss Company of Germany; Sir Howard Grubb, Parsons and Company of England; the Warner and Swasey Company of Cleveland; and J. W. Fecker of Pittsburgh. The preliminary specifications stipulated the general form of the mounting but left considerable latitude in detail. The Warner and Swasey Company did not submit any tender and the design of the Carl Zeiss firm was not attractive as it was of a very radical nature. There was not much difference in the designs of the other two firms but after due consideration it was decided to accept the tender of Sir Howard Grubb, Parsons and Company, England. This was a very fortunate choice because the decrease of the pound sterling and the inflation of the American dollar later made the cost of the telescope very much less than it would have been had the contract been let in the United States.

The general form of the mounting is shown in Fig. 2 and a photograph as it appeared in the workshops prior to shipment is shown in Fig. 3. The essential features of any mounting are the tube which supports the optical parts and two axes of rotation at right angles to each other. The *polar axis* (*SS'* in Fig. 2) must point to the celestial pole and the *declination axis D* to which the tube is attached provides another degree of freedom so that the tube may

be pointed to any part of the sky. The polar axis is rotated by clockwork *I* in such a way that the telescope will continue to follow an object as it moves from east to west across the sky in its diurnal rotation. This is the equatorial form of mounting.

There are many forms of the equatorial mounting, which differ in the way the the tube is attached to the de-

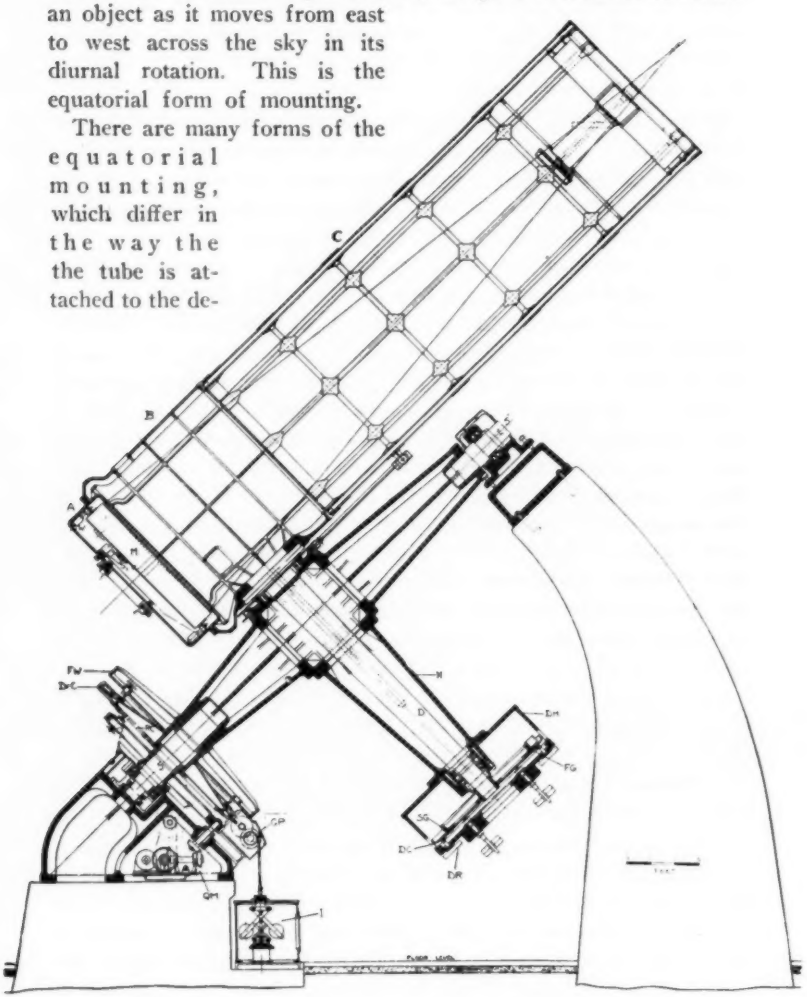


FIG. 2. Vertical north-south section of the 74-inch telescope.

clination axis, the latter attached to the polar axis, and the way in which the polar axis is supported. The kind of mounting selected for the 74-inch telescope is usually called the English type. As can be seen from Fig. 2, the polar axis is supported at both ends by two piers and the tube is carried on one end of the declination axis. In very heavy telescopes the polar axis is sometimes built in the shape of a large O and the declination axis supported by bearings at each

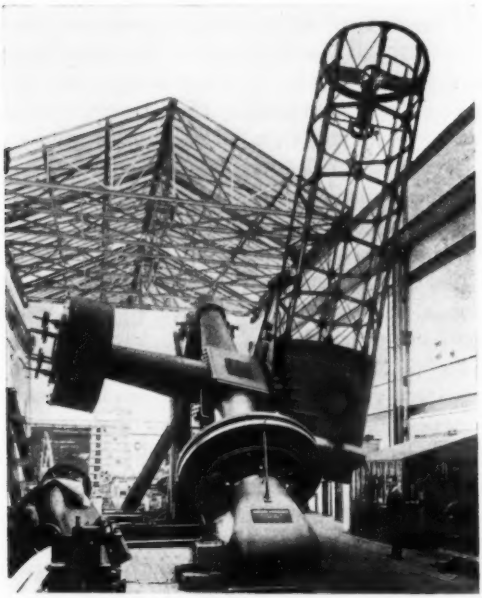


FIG. 3. The 74-inch telescope, as mounted in the works at Newcastle. View from the south.

end of the short diameter. This design is adopted in the mounting of the 100-inch telescope at Mount Wilson, California. In other telescopes the declination axis is attached to the polar axis beyond the two bearings of the latter. The 40-inch telescope of the Yerkes Observatory, Chicago, is an example of this type of mounting. In other telescopes again the polar axis is built in the form of a mas-

sive fork with two prongs, and the tube of the telescope is mounted between the arms of the fork, as in the 60-inch telescope of the Mount Wilson Observatory. Each type has its peculiar advantages in regard to strength, accessibility, and freedom of motion. The form adopted for Toronto has proved very successful in the 72-inch telescope at Victoria, B.C.

When the contract was awarded in 1930 the main outlines only of the instrument were specified and Sir Howard Grubb, Parsons and Company began work on the detailed drawings. It seemed advisable for the author to spend some time in England going over the plans of the instrument with the manufacturer, and F. Jno. Bell, M.E.I.C., the Canadian representative of the firm, arranged to have the author visit Newcastle while the essential features were being drafted. This enabled much more rapid progress to be made than would have been possible if all the details had to be settled by correspondence.

On the author's arrival in England early in July 1930 the drawings were found well underway. Fortunately the firm had recently completed the 36-inch reflecting telescope for the Edinburgh Observatory and were engaged on a 40-inch telescope for the Stockholm Observatory. As there are many parts very similar in all telescopes, it was easy, from the parts of the 40-inch, many of which were in the workshop, to form a picture of the proposed new telescope. The completed drawings of the Edinburgh telescope were also a great help. In addition, the author had had a long experience with the 72-inch reflecting telescope at Victoria, B.C.; and since the proposed mounting was very similar to this, conferences with Mr. C. Young, the manager of the optical works, enabled rapid progress to be made on the final design. When the author left towards the end of August no work on the actual construction had been done but the plans were so far advanced that construction was started in the fall.

The Tube

The tube of the telescope, which immediately supports all the optical parts, is made in three sections. These are the mirror cell *A*, the centre piece *B* and the skeleton *C*, and are shown in Fig. 2. There are several features that the tube must possess. It must be as

light as possible but must carry the 5,000-pound mirror at the bottom and the small mirrors at the top with a minimum amount of flexure. It must permit a free circulation of air so that light rays, in their passage through the tube to the main mirror and back, travel in a homogeneous medium. It must be capable of adjustment for alignment so that the optic axis is truly at right angles to the face to which the declination axis is attached. In order to reduce vibration to a minimum it should be mounted as close to the polar axis as possible.

The mirror cell consists of a ribbed steel casting, weighing about 2,100 pounds. The mirror is supported on the bottom by a system of discs 7 inches in diameter in three sets of three each. These supports are shown in Fig. 2 at S_1. Each disc is mounted on a universal joint and the web-work which supports each set of three discs can be moved in or out to set the mirror with its face perpendicular to the optic axis. The disposition of the various discs is such that each carries its share of weight. Very careful attention was also given to the edge support. It is surrounded by arcs of a strong steel rim which fits into a groove in the disc. Heavy weights shown at *W* are attached to this rim by universal joints and are also attached by brackets attached to the interior wall of the mirror cell. When the tube is vertical there is no thrust on the edge of the mirror, but as the tube assumes a horizontal position the weights act as levers, with the brackets on the mirror cell acting as fulcrums, and support the resolved component of the weight of the mirror so that in all positions the mirror is, as it were, floated. This might seem an elaborate system of support, but the mirror is so sensitive to any distortional stresses that there is danger of the disc being warped if the stresses are not as uniform as possible in all parts. The mirror cell is bolted by a flange to the central casting.

The centre piece of the tube is also of steel and is heavily ribbed, weighing 4½ tons. A boss is cast on one side where it bolts to the declination axis. Instead of making a perfectly flat contact between the flange on the declination axis and the centre piece, they touch along a rim only. The purpose of this precaution is to reduce the rate of flow of heat from the tube to the declination axis and thence to the rest of the massive parts of the telescope. This flow of

heat has a tendency to take place in the early evening when the telescope is first put into use and the result seems to be that the part of the tube next the polar axis becomes a little cooler or warmer than the outer parts. There is then a temperature gradient across the disc and this produces a slight cylindrical warping and consequent astigmatism in the reflecting surface. It is necessary that the face of the boss and the two faces, where the mirror cell is bolted on at the lower end and the tube at the upper, be at right angles. The operation of truing these up may be seen in Fig. 4.

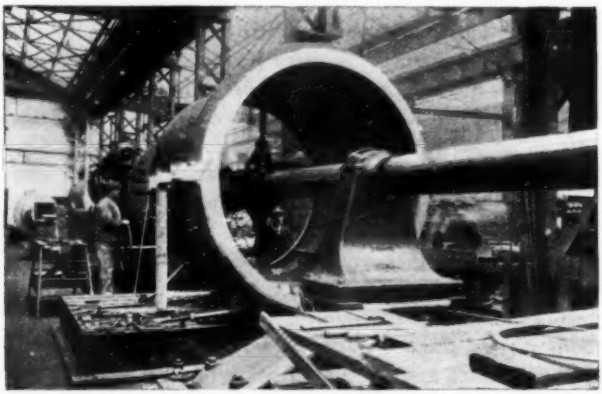


FIG. 4. Truing-up the faces of the centre-piece.

Immediately above the mirror and attached to the centre piece is an iris diaphragm similar in construction to that used in ordinary cameras. It is operated by a graduated hand-wheel on the outside of the tube and may be used to stop down the telescope and it serves also as a protection to the mirror when closed. It is shown at half aperture in Fig. 5.

The skeleton part of the tube, which is bolted to the upper flange of the centre piece, is made of duralumin I-beams, cross-braced by rods also of duralumin threaded right and left hand at the ends into T-anchors. By means of these brace rods, which can be seen in Fig. 3, the tube may be made to twist slightly or to shift in any direction without twisting. The rods are tightened to a point where each is

under tension in any position of the tube. Careful tests of the completed tube have shown that, in the extreme position of flexure, the outer end does not sag more than one-sixteenth of an inch. The skeleton part of the tube supports at its upper end the secondary mirrors which may be of the Newtonian or Cassegrain form. The 74-inch telescope is designed to be convertible to either form. In Fig. 3 is seen the Cassegrain mirror in place, and in Fig. 2 the position the Newtonian mirror occupies is shown by dotted lines (at the upper end of the tube). Sectional elevations of these two attach-

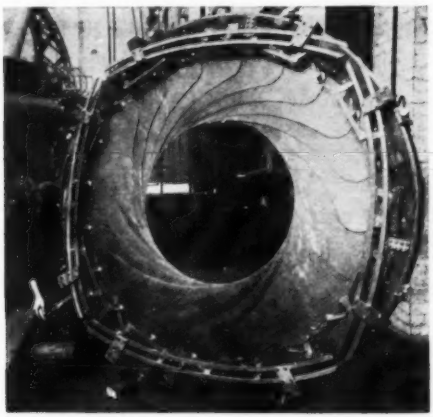


FIG. 5. Iris diaphragm at half aperture. The workman at the left is turning the wheel to change the aperture.

ments are shown in Figs. 6 and 7. Very convenient arrangement is provided in both these mirrors for bringing them into alignment with the axis of the tube, by means of the screws B, B. By shifting the dowel pin C (Fig. 7) in the Newtonian form the mirror can be rotated and the rays of light brought to the side of the tube in any one of four positions. This is almost essential because, in working at the upper end, it is convenient to bring the focus to that side of the tube which is the easiest to reach. By loosening the screws A, A, the Newtonian may be removed and the Cassegrain fastens to the same flange. When the Cassegrain mirror is in place the observer

is situated at the base of the tube. In a large telescope of the reflecting type the changes in temperature, causing expansion and contraction in the tube and mirror, alter the position of the focus. Changes in the focus may be made by altering the position of the Cassegrain mirror and in the 74-inch telescope this is done by a small motor mounted in the tube which attaches the mirror in position. The observer has only to touch a button at the lower end of the tube and the focus is adjusted in or out as desired.

The Declination Axis and Housing

The declination axis, to which the tube of the telescope is attached, consists of a steel forging 13 feet long with a flange at the

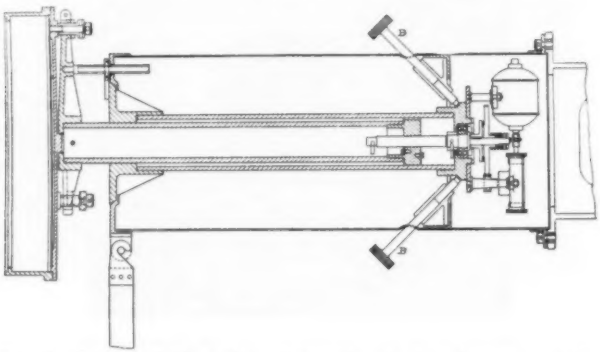


Fig. 6. Longitudinal section of the Cassegrain mirror mounting.

inner end 3½ feet in diameter. Its weight is about 3½ tons. A hole has been trepanned through its centre to permit the electric wiring to pass to the tube and to the outer end. It is supported at the inner end by a radial ball-bearing 17 inches inside diameter, and at its outer end is carried by a radial bearing and double thrust bearing fitting into a tubular steel casting (*H* in Fig. 2) which is called the *declination sleeve*. All the bearings have been specially made with considerably less clearance than in commercial bearings. A spur gear (*SG* in Fig. 2), keyed to the outer end of the declination axis, serves to turn the tube quickly in declination. The power for this motion

is supplied by a motor inside the *declination housing DH*. A photograph of this motor and gearing is shown in Fig. 8. It can be clamped or unclamped by a magnetic clutch, the controls for which are mounted on the pier of the telescope. Bolted to the large spur gear is a graduated circle *DC* (Fig. 2) which by an index enables the observer to read the declination at which the tube is set. This *declination circle* is divided to single degrees, but in order to read the declination more accurately a fine spur gear *FG* bolted to the graduated circle drives two small drums *DR*, and these are graduated to a least reading of five minutes of arc. Small electric lights

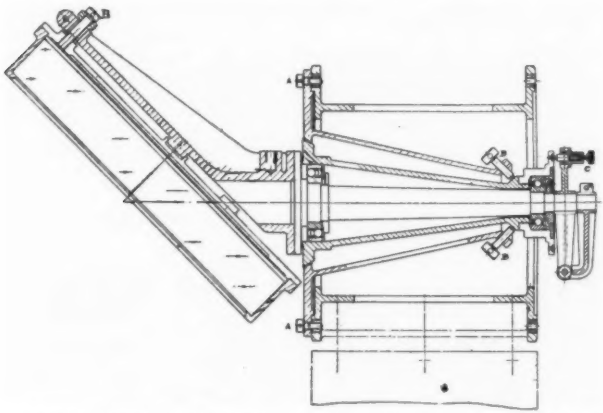


FIG. 7. Longitudinal section of Newtonian mirror mounting.

illuminate the declination circle and drums so that the reading may be conveniently seen from the operator's position beside the pier. The declination housing is made intentionally heavy so that its weight counterbalances the weight of the tube. Additional weights are attached to the housing to adjust the balance. It can be seen from Fig. 2 that no extra weight has been attached to the declination axis proper, thus reducing flexure to a minimum and facilitating a free motion in declination. When the telescope has been brought to the correct declination setting, within a minute of arc, the quick motion gear is disengaged and the observer, on looking through the

telescope, will see the star, but usually not in the centre of the field of view. It is necessary to have some fine adjustment whereby the tube may be moved by very small amounts. The mechanism which effects this is called the *declination slow motion.* It is shown in Fig. 2 and in Fig. 3 between the polar axis and the tube. A fabricated steel arm about seven feet long is mounted on a V-ring which can be clamped or unclamped to the polar axis. The outer end of the arm carries a nut mounted on a link motion which can be moved in either direction along a screw attached to a bracket fastened on the tube. A motor operates a two-speed gear to turn this screw for

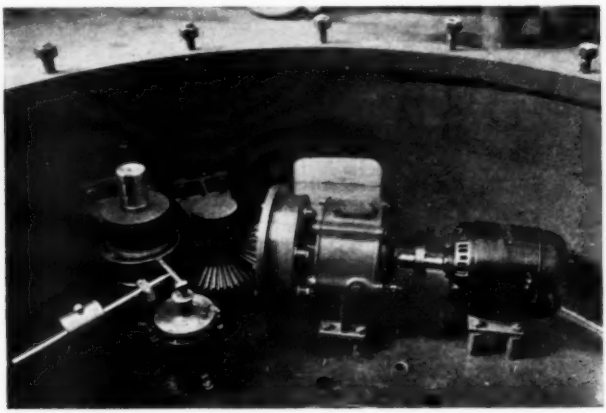


FIG. 8. Gear for quick motion in declination.

giving the slow motion in declination. The motor is operated by two separate switches. For the faster motion a dog-clutch, operated by a solenoid in parallel with the motor, connects the gear to the slow motion screw and moves the tube fifteen minutes of arc in one minute of time. For the slower motion an electro-magnet brings a differential gear into action and the tube moves thirty seconds of arc in one minute of time. The circuit which actuates the magnetic clutch in the declination housing for quick motion is interlocked with the clamping motor on the V-ring so that it is impossible to have the two clamps engaged at the same time.

The Polar Axis and Driving Gear

The polar axis, which carries the declination axis and housing, is best seen in Fig. 9 where it is shown on a lathe. It consists of three sections, a central hollow steel cubical casting to which is bolted two tapered hollow steel tubular castings. Forged steel pivots are shrunk into the ends of the steel castings. Figure 9 shows the operation of truing the polar axis. It is 22 feet long and weighs 9½ tons. Having been trued up it was never taken apart but henceforth treated as a unit. It runs in self-aligning ball bearings with a

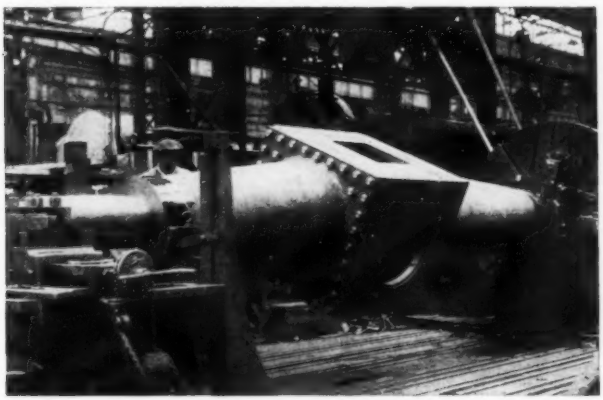


Fig. 9. Truing-up the polar axis.

ball thrust bearing at the lower end. The housing at the upper end provides means of adjustment in elevation and azimuth to bring the axis SS' in line with the celestial pole. Keyed to the lower end of the polar axis is a large spur gear S which engages with the quick motion motor QM in Fig. 2 for moving the telescope in right ascension. This motor is engaged with the gear by a magnetic clutch. When the clutch is engaged and the motor started, the telescope rotates in right ascension, and in order to bring the telescope quickly to rest when the motor is released, the clutch continues to engage for a few seconds and acts as a drag. This is a very convenient arrangement in preventing the overrunning of the telescope beyond

The Driving Clock

The position of the driving clock is shown at *I* in Fig. *2* and a cross-section through the vertical spindle is given in Fig. 12. The cross-arm governor *G* is driven by the weight *W*. The motor *M* turns at the right speed to keep the weight floating on its vertical guides. Ordinarily if the motor is turning at the correct rate the position of *W* will be stationary and the outer housing of the differential gear *U* will be at rest. But if the motor turns too fast or

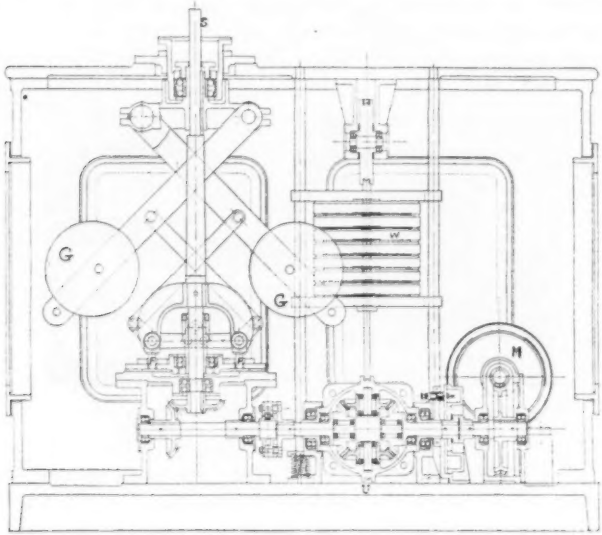


Fig. 12. Sectional view of the driving clock.

slow the weight rises or falls and the outer housing turns, without affecting, however, the torque applied to the governing spindle. In order to keep the weight *W* suspended and to govern the motor, the weight is attached to a lever arm, not shown in the drawing, which actuates a resistance in series with the motor slowing the latter down if the weight gets high and speeding it up if the weight falls low. As the governors speed up, the link motion spreads and brings into

play two friction pins at *F, F,* and the speed is checked. The moment that these engage can be regulated by turning the heavy weights *G, G,* which are mounted eccentrically. A clock of this type runs very accurately but not with the precision necessary to keep the image of the star perfectly stationary. Therefore, instead of gearing the spindle *S* directly to the driving worm, it communicates to a gear plate shown in Fig. 3, and at *GP* in Fig. 2, the function of which is to correct for any small irregularities in the clock drive and

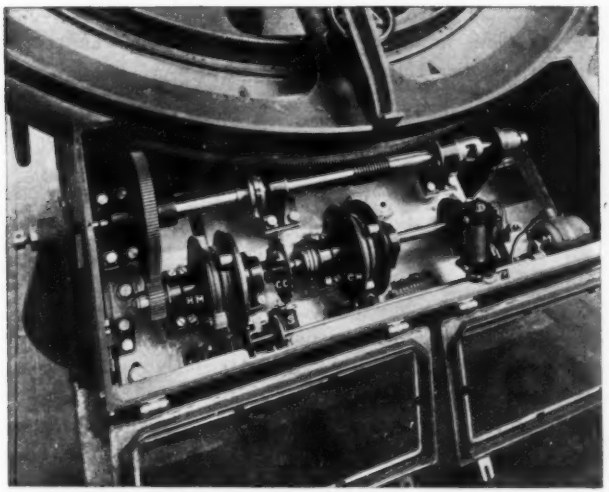


FIG. 13. Gear plate and driving worm.

at the same time provide means of slow motion of the telescope in right ascension if it is desired to shift the position of the star in the field of view. The spindle *S* of the driving clock connects with the worm and worm wheel of the gear plate shown at *D* in Fig. 13. If the clock is driving at exactly the right rate this shaft turns one revolution in twenty-four seconds. Mounted on this shaft at *CC* is a thin disc in the circumference of which are cut twenty-four V-shaped notches, and into these notches beats the armature of a solenoid which is connected to the seconds beat of a sidereal master

clock. Provided the disc *CC* runs at the correct rate, the armature accurately strikes the depressions; but if the wheel runs too fast or slow, the armature shifts the wheel slightly and it is connected with the differential *HM* to keep the worm drive in synchronism with the notched wheel *CC*. For a slow motion the differential *HM* may be rotated by the motor *M* and for a still finer motion the differential *GM* can be locked or released by a dog-clutch. The motion imparted by the motor *M* is never sufficient to overcome completely the normal rate of drive, so that the driving screw is always engaged with the driving circle and hence all difficulties of backlash avoided.

The complete mounting as described above was received in Toronto on October 15th, 1933.

The Building and Dome

The building to house the telescope, though out of the line of ordinary construction, did not require so long to complete. The contract for it was let in November 1931, and it was received on July 31st, 1933. In the meantime the piers to support the telescope and the foundations of the building had been built.

Figure 14 shows the cement piers in place and the nature of the surrounding country. The site chosen is a hill about 800 feet above sea level and 100 feet above the surrounding country, 12 miles north of the city limits of Toronto. The piers consist of reinforced concrete and extend 25 feet underground to a foundation of hard clay which extends farther down for more than 150 feet. On the east side of the pier a pit 6 by 10 feet extends to the bottom of the foundations. An elevator is mounted in this pit for removing the mirror and mirror cell. The mirror can be readily taken off for the purpose of resilvering.

Figure 15 shows the circular building and dome as it stood on September 7th. This picture shows the second shutter being hoisted to its place. Since then the telescope has been put in place and the dome covered. As the construction of the building and dome presents a number of unusual features a brief description will be of interest. The entire building is of steel construction. The circular base and dome have double walls, and open louvres at the base of

the building admit air which circulates to the top and exits through baffle plates at the top of the dome. The inside and outside of the dome is covered with "agasote," a kind of hard paper product, and the outside is further protected by a sheeting of copper. By this means the interior is kept cool during the day, and in the evening when observations are started the whole building soon assumes the temperature of the outside air, thus the definition is not interfered with by heated air currents which would undoubtedly be the case if any quantity of heat were stored in the walls.

The dome, which weighs about eighty tons, rests on twenty-four

FIG. 14. The cement piers as seen from the roof of the Administration Building to the south-east. The circular foundation for the building is 61 feet in diameter. Richmond Hill is in the distance.

rollers 27 inches in diameter mounted on self-aligning ball bearings and running on a circular track. Lateral rollers keep the dome in position as it is rotated. The rotation is effected by means of an endless steel cable passing around an annular channel ring fixed to the base of the dome and over two tangent pulleys to a winding gear. The dome is 61 feet in diameter and has an opening at one side, 15 feet wide, extending from the bottom to 7 feet beyond the zenith. Two parallel shutters run on rails at the top and bottom of the dome and are operated by wire ropes connected to a motor-driven gear which opens or closes the two shutters simultaneously. To protect

the telescope from wind blowing in at the open shutter, two wind screens, motor operated and consisting of heavy sail cloth, can be used to cover the part of the opening not in use. One runs from the top of the opening downward and the other from the bottom upward and are guided in tracks fixed to the inside of the shutter opening. A novel feature of the dome, and one which should make it more

FIG. 15. Raising the second shutter of the dome (Sept. 7, 1933).

convenient to operate than any previous models, is the method of access to the upper end of the tube. Two parallel segmental platforms are fixed to the inside of the dome, the lower one at the base of the opening and the upper one at a 16-foot higher level. Rails are mounted on these platforms and a circular arc bridge connects the two platforms. The bridge is shown in Fig. 16. The entire bridge can be moved laterally on the rails of the platforms and a small observing carriage travels up the curved arch. The small observing platform can be swung around on a pivot to enable the observer to

place himself in a convenient position with respect to the eyepiece of the telescope.

No effort has been spared by the manufacturers to make the entire mechanism, mounting and dome in the best way possible. The workmanship is of the highest quality throughout and when finally completed the telescope will be the largest in the British Empire.

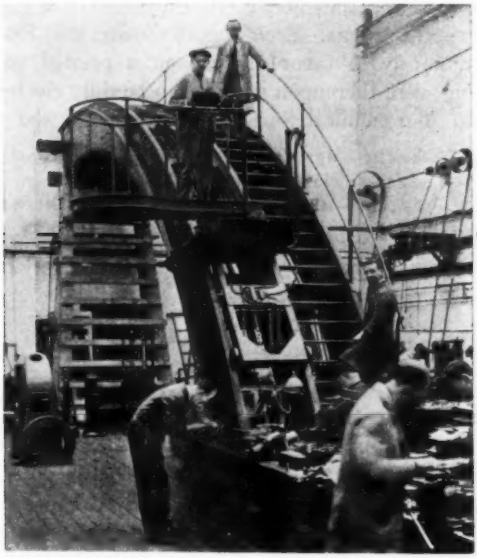


FIG. 16. The observing platform. By it the observer can reach the upper end of the tube when it is in any position.

The magnitude of the telescope will make it a powerful instrument of research, and the major part of the programme of the observatory will be devoted to investigations into the motions and distribution of the stars. One evening per week however will be devoted to viewing the heavens, when the public will be invited to visit the observatory and look at the planets, the moon and other objects in the sky.

Note.—The blocks used in Figs. 3 to 16 were courteously loaned to this JOURNAL by *The Engineering Journal*, the organ of the Engineering Institute of Canada.—*Editor.*

ANNUAL GENERAL MEETING OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

THE meeting was held on Tuesday, January 9, 1934, at 8 p.m. in the University of Toronto, Dr. R. K. Young, the president, being in the chair.

The minutes of the previous annual general meeting were read and approved.

Mr. H. F. Balmer and Mr. F. L. Troyer were appointed scrutineers to count the ballots. Their report showed that the voting was almost unanimously in favor of the names printed on the ballot. The following were thereupon declared to be duly elected as officers of the Royal Astronomical Society of Canada for the year 1934:

HONORARY PRESIDENT—Mgr. C. P. Choquette, M.A., Lic. Scs., Montreal
PRESIDENT—Lachlan Gilchrist, M.A., Ph.D., Toronto
FIRST VICE-PRESIDENT—R. E. DeLury, M.A., Ph.D., Ottawa
SECOND VICE-PRESIDENT—J. A. Pearce, M.A., Ph.D., Victoria, B.C.
GENERAL SECRETARY—R. A. Gray, B.A., 198 College St., Toronto
GENERAL TREASURER—J. H. Horning, M.A., Toronto
RECORDER—E. J. A. Kennedy, Toronto
LIBRARIAN—R. A. Gray, B.A., Toronto
CURATOR—R. S. Duncan, Toronto
COUNCIL—D. S. Ainslie, M.A., Ph.D., Toronto; F. Napier Denison, Victoria, B.C.; Miss A. Vibert Douglas, Ph.D., Montreal; Wm. Findlay, Ph.D., Hamilton; A. R. Hassard, K.C., Toronto; E. A. Hodgson, M.A., Ottawa; E. H. McKone, B.A., B.Paed., London; J. Patterson, M.A., Toronto; John Satterley, M.A., D.Sc., Toronto; L. A. H. Warren, M.A., Ph.D., Winnipeg.

The General Secretary's report was received and approved. The Reports of the Secretaries and Treasurers of the various Centres were also presented and approved.

The General Treasurer read his annual financial statement. It was moved by Mr. J. E. Maybee, seconded by Mr. E. J. A. Kennedy, that this statement, which was duly audited, be adopted. (Carried.) The Librarian and the Curator also presented their reports, which were duly approved.

The auditors, Mr. A. R. Hassard, and Mr. J. E. Maybee, were thanked by the meeting for their voluntary work on the books of the Society; both gentlemen were re-appointed for the year 1934.

E. J. A. KENNEDY, *Recorder.*

REPORT OF THE GENERAL SECRETARY

There is little to report for the year 1933. The usual requests for the JOURNAL and for the OBSERVER'S HANDBOOK are received from all over the world, and are supplied as generously as possible.

The Society suffered a great loss last November in the death of Rev. Dr. D. B. Marsh, of Hamilton, who served for years on the council and whose efforts resulted in the establishment recently of a new centre in Hamilton, Ont. He resided for a time in Bermuda, where his work was recognized.

R. A. GRAY, *General Secretary.*

MEMBERSHIP OF THE SOCIETY

The membership of the Society on December 31, 1933, as shown by the reports of the different Centres, was as follows:

	1932	1933
Toronto	175	173
Ottawa	61	62
Victoria	116	112
Montreal	110	111
Winnipeg	55	69
London	71	60
Hamilton	66	56
Vancouver	71	67
Edmonton	48	40
Members at Large	104	108
Total	877	858
Subscribers to JOURNAL	68	68

E. M. BUDD, *Assist. Secretary*

REPORT OF THE LIBRARIAN

As intimated at the last annual meeting, consideration has been given to the housing of the library. A memorandum issued by Dr. Chant to every member of the Council suggests that the more technical portion of the library, including a number of journals and

magazines, might be loaned to the new David Dunlap Observatory, which is under the control of the University of Toronto, and thus made available to advanced students of astronomy. The memorandum is submitted immediately below. A committee was appointed to endeavour to draft suitable arrangements for the loan which would secure for the members of our society the use of these volumes whenever desired. The report of this committee will be submitted to the next meeting of the Council for approval. The space in the library made available by the transfer of these volumes will make more easily accessible the more popular works of the library.

Additions to the library during the year include periodicals from

Canada and the Empire	185
The United States	209
Other Countries	231
Total	625
Number of books borrowed by members	95
The JOURNAL is sent in exchange to—	
Places in Canada and the Empire	40
The United States	49
Other Countries	48

The thanks of the Society are due to Dr. R. K. Young and to Mr. F. L. Troyer for sorting and re-arranging the store of past issues of the JOURNAL. They spent considerable time in making these copies available for distribution when asked for.

R. A. GRAY, *Librarian.*

MEMORANDUM RELATING TO THE DAVID DUNLAP OBSERVATORY AND THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

The David Dunlap Observatory will begin its scientific work in the near future. One of its urgent needs is a good working library. Some fifteen years ago when a modern observatory was planned for Toronto it was proposed that accommodation should be provided for the Royal Astronomical Society of Canada's library, which was to be maintained by the Society for use by all who wished to consult it. At that time it was expected that the Observatory would be located on Bathurst Street in what is now Forest Hill Village.

When, after many years of waiting, Mrs. Dunlap agreed to donate to the University an Observatory of the largest size, the site which had been chosen was considered unsuitable, being too small in area and too near the city. The Observatory, in its location near Richmond Hill, is anxious to co-operate with the Society. The site is too distant for regular meetings to be held there, but the Observatory will be pleased to arrange for special meetings for observation and for some social gatherings.

The Observatory is anxious, also, that the Society should come to its aid in the matter of its library. The Society's library has a reasonably good collection of books on astronomy; this is the more popular portion. But for many years it has been accumulating the publications of observatories and other societies, many of them being sent in exchange for our JOURNAL. This portion of the library is of a technical nature, intended chiefly for the professional astronomer. For some years a number of these more technical publications have been on loan to the Department of Astronomy in the Physics Building of the University.

The Observatory wishes to be permitted to move to the new building these sets of publications and any others of the same nature which may be agreed upon by a committee appointed by the Council of the Society. The Observatory would catalogue these volumes and pamphlets and they would be at the service of the members of the Society. Indeed it is believed that they would be more easily available to the members than they have ever been heretofore. The Observatory would endeavour to complete any sets which are defective and they also will be at the service of any one who can use them.

The Society and the University are both organized for service to the public and the relations between the two bodies for many years have been cordial and helpful. The Observatory wishes to extend this co-operation.

(Signed) C. A. CHANT

Director of the David Dunlap Observatory.

November 1, 1933.

ADDED FEBRUARY 26, 1934

On January 5, 1934, the Council received the report of the Committee and ordered that it be sent to all members of the Council, with the statement that it would be acted upon at a meeting to be held on February 2. All letters received from the members of the Council approved the report and on the last-named date it was passed unanimously. The report follows.

REPORT OF A COMMITTEE OF THE COUNCIL OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

The committee was appointed by the Council of the Society on November 28, 1933, to consider the Memorandum from Professor C. A. Chant, Director of the David Dunlap Observatory, asking the Council to assist in establishing a library in the new observatory. The committee realizes the importance of

this great institution and believes that in the coming years it will make important contributions to the science of astronomy and will bring distinction to the neighbourhood and to all Canada. The committee thinks the Council should cordially co-operate with the University in providing a library for the observatory, and begs to recommend:

1. That the more technical portion of the Society's library, as designated in the appended list, be loaned to the Observatory.
2. That the Observatory shall give the Society through the Librarian of the University a receipt for the various publications loaned.
3. That the Observatory shall undertake to replace any publications which may be lost or damaged.
4. That for the present the Society shall continue at its discretion to bind the current publications as the volumes are completed.
5. That a list of the publications loaned shall be supplied to the Librarian of the University who may obtain for consultation any of the publications, in the same manner as is followed in the departmental libraries of the University. It is understood that, as proposed by Professor Chant in his Memorandum, the members of the Society shall have access to the entire library of the Observatory on the same conditions as members of the University.
6. That the loan be for three years, at the end of which time it may be renewed and the terms revised.
7. That this agreement with the Observatory shall become valid when it is approved by the Board of Governors of the University.

(Signed) R. A. GRAY, *Convener.*

The above report was sent to Dr. H. J. Cody, President of the University of Toronto, who presented it to the Board of Governors of the University at their meeting on February 22. The Board cordially accepted the proposal.

REPORTS OF SECRETARIES OF CENTRES

TORONTO CENTRE

Eighteen new members were elected during the year just passed. Twenty resignations were received. The membership numbered 175 at the commencement of 1933. There is therefore a net loss of 2 for the year, with the list showing 173 names. Of these, 117 are resident in Toronto and vicinity, and 56 are non-residents who have specifically expressed a desire to be members of Toronto Centre. Our number includes 8 life members.

We would like to call attention to the fact that our membership

has remained stationary for a number of years past and would like respectfully to urge each member to interest others to become members. They will not only be opening up a great field of interest and enjoyment to the prospective members, but will also be aiding the Society financially. We can materially extend our activities if our bank balance were greater.

During the year twelve meetings were held. The subjects and speakers were as follows:

January 31—R. A. Gray, B.A.: Copernicus; J. R. Collins: Orion.
February 14—Prof. D. S. Ainslie: Electrical Instruments for Astrophysical Measurements; A. R. Hassard, K.C.: Taurus.
February 28—H. F. Balmer, M.A.: Man's Place in the Universe; R. A. Gray, B.A.: Scorpio.
March 14—Prof. C. A. Chant: Precession of the Equinoxes.
March 28—Prof. Wm. Findlay: Gravitation; M. Stewart: Sagittarius.
April 11—Prof. R. K. Young: The Tides; G. Hepburn: Gemini.
April 25—Sir Frederic Stupart: Recollections of early days at the Toronto Observatory.
October 10—A. R. Hassard, K.C.: Summer Observations.
October 24—F. T. Davies: International Polar Year and the Canadian Expedition to Chesterfield Inlet.
November 7—F. L. Harvey: Saturn; F. L. Troyer: Shooting Stars, and how the Amateur Astronomer may observe them.
November 21—Dr. Peter M. Millman: Harvard Observatory, past and present.
December 5—K. O. Wright, B.A.: Theories of the Universe, ancient and modern.

A short talk on one of the planets was given at each of the autumn meetings: Jupiter, by Mr. G. Hepburn; Venus, by Mr. E. J. A. Kennedy; Mercury, by Mr. J. R. Collins.

E. J. A. KENNEDY, *Secretary*.

EDMONTON CENTRE

The annual meeting held in the Corona Hotel on December 12 marked the close of the second year of the existence of the Edmonton Centre of the Royal Astronomical Society of Canada.

During the year there were seven regular meetings as well as the annual meeting. The speakers and their subjects for the meetings were as follows:

January 12—Prof. E. S. Keeping: The Calendar.
February 9—Mr. Clinton Constantinescu: The Rocket.
March 9—Mr. F. S. Simpson: The Planets.
April 13—Dr. E. H. Gowan: Sun Spots.
May 13—Dr. J. A. Pearce: Diffuse Matter in Space.
October 12—Dr. J. W. Campbell: How the Diameters of the Stars are Measured.
November 9—Mr. M. J. Hilton: The Life and Work of Johann Kepler.
December 12—(Annual Meeting). Professor L. H. Nichols: Some Popular Fallacies in Astronomy.

At the beginning of the year there were forty-nine members. During the year there has been a decrease of seventeen from resignations and removals, and an increase of thirteen by new members admitted, so that the membership now stands at forty-five.

The election of officers for 1934 resulted as follows:

Honorary President—Dr. J. W. Campbell.
President—Mr. M. J. Hilton; Vice-President—Dr. E. H. Gowan.
Secretary—Mr. H. H. Beach; Treasurer—Mr. W. H. Poole.
Council—Mrs. J. A. Clarke, Mr. W. O. Coulman, Mr. T. W. Hamilton, Mr. A. B. McKim, Professor E. S. Keeping.

FRANCES M. FISHER, *Secretary.*

HAMILTON CENTRE

During the past year nine meetings have been held, including a field night in June on the grounds of Mr. W. T. Goddard, when all available telescopes were set up for the use of the members. Many interesting addresses were given during the year including the following:

January—Prof. H. F. Dawes: Spectra.
February—Dr. D. B. Marsh (now deceased): Time.
March—Prof. Wm. Findlay: Gravitation.
April—T. H. Wingham, B.A., Sc.: Jupiter.
May—J. Patterson, M.A., F.R.S.C.: Some Principles of Weather Forecasting.
October—Brief addresses by various members regarding personal observations during the summer.
November—Prof. A. E. Johns: Time.
December—Mr. J. R. Collins, Toronto: Our Earth Among the Stars

In addition, the president, Mr. W. S. Mallory, has given a brief

blackboard talk at each meeting, on the sky for that particular evening.

The membership of the local centre continues to be maintained, the new members making up for those who have retired. Interest and enthusiasm have been kept up by the hard work and enthusiastic energy of the retiring president, Mr. W. S. Mallory. We look forward to a continuance of the good work during 1934 under the presidency of Professor Findlay.

J. A. LITTLE, *Secretary.*

LONDON CENTRE

During the year 1933 there were nine meetings at which the following subjects were discussed:

January 13—Mr. E. H. McKone: Astronomical Terms Everyone Should Know. Attendance 34.

February 10—Dr. H. R. Kingstton: The Planet Mars. Attendance 27.

March 10—D. B. Marsh (now deceased): Our Universe, its Size, Structure and what is Beyond it. This was a public meeting. Attendance 52.

April 13—Mr. F. H. Coates: Astronomy, the Science of the Ages. Attendance 25.

May 12—Rev. W. G. Colgrove: The Moon. Attendance 22.

June 9—Annual picnic and observation meeting. Attendance 34.

October 13—Dr. H. R. Kingston: Saturn. There was a short period for observation. Attendance 38.

November 10—T. C. Benson: Demonstration of a Constellation and Star Finder, and also of the theory and use of Foucault's Pendulum. Attendance 25.

December 8—Annual meeting and social evening. There was a demonstration of his improved Planetarium by Rev. W. G. Colgrove, followed by games and refreshments. Attendance 31.

Total membership for the year was 60. There were three meetings of Council, on Dec. 30, 1932, May 1, and Sept. 4, 1933 at which the programmes for the year were arranged.

N. MORRIS, *Secretary.*

MONTREAL CENTRE

New members numbered two. The number of members at the present date, November 2, 1933, is 111.

Five meetings were held during the twelve months from October 1, 1932, as follows:

October 27—Mr. Harper Hall and others: The 1932 Total Solar Eclipse.
December 8—Dr. A. Norman Shaw: Fundamental Experiments in Thermal Radiation.
February 2—Abbé Lemaitre, of Louvain: The Expanding Universe.
May 4—Observational Meeting. (4 telescopes on McGill Campus).
September 25—Abbé Lemaitre, of Louvain: Developments of the Theory of Expanding Space.

A. VIBERT DOUGLAS, *Secretary*.

OTTAWA CENTRE

During the year, three public lectures were held in the Lecture Hall of the Victoria Memorial Museum, and three technical talks were given at the Dominion Observatory.

The public lectures were as follows:

January 27—C. M. Sternberg: Canadian Dinossaurs.
February 17—J. U. Beauchemin, C.E.: The Gyrocompass and Echo Sounder.
March 10—John Patterson, M.A.: The International Polar Year 1932-1933; Its Organization and Purposes.

The technical talks were:

January 19—Dr. D. C. Rose: Cosmic Rays.
March 23—R. Meldrum Stewart, M.A.: The Mathematical Theory of the Foucault Pendulum (Part 1).
March 30—R. Meldrum Stewart, M.A.: The Mathematical Theory of the Foucault Pendulum (Part 2).

In addition to these, five emergency meetings of the council were held at the Dominion Observatory.

Our membership at the beginning of the year was 61. During the year two members died, J. S. Imlach, and W. H. Herbert; two members resigned and one was transferred; six new members joined the Centre; so that we end the year with 62 members.

A slight change was made with regard to the annual meeting. Since in former years the attendance on such occasions had been exceedingly small, it was felt that an opinion from the members regarding the officers for next year would be very much appreciated. With this in mind, a ballot sheet was sent to all members and the results have been very gratifying.

As in other years, the Saturday evening programme of the Dominion Observatory was sent to members, this being made possible through the kindness of Mr. R. Meldrum Stewart, the Director.

MIRIAM S. BURLAND, *Secretary.*

VICTORIA CENTRE

Membership:

Membership per Report of Secretary at close of 1932			116
Resignations during 1933	27		
Deaths	1		
	—	28	
Members elected during 1933		24	4
Membership at close of 1933			112

Membership is composed as follows:—

Local Members	74
Out-of-Town Members	38
Junior Members (an increase of 7 during the year)	15
Ladies	20
Honorary Members	1
Life Members	2

Of the 74 local members 19 are ladies.

MEETINGS:

Ten regular and seven Council meetings were held during the year. Average attendance at the regular meetings was 49.

The Council also initiated a summer lecture course, report on which was published in the JOURNAL for October, 1933. Of the eleven non-members attending this course, five have joined the Society.

GENERAL:

In his report for last year the Secretary mentioned the real help that members can give to their officers by prompt payment of dues and by interesting their friends in becoming members of the Society.

He would like to take this opportunity to bespeak, on behalf of the incoming Secretary, handicapped by a reduced membership and a financial deficit, your earnest attention to these two matters.

Finally the Secretary-Treasurer desires most sincerely to thank

all those who by their promptness, generosity and enthusiasm have enabled the Centre to come through this year of financial stress as well as it has, and to wish all members a happy Christmas and a prosperous New Year. H. BOYD BRYDON, *Sec.-Treas.*

WINNIPEG CENTRE

We are pleased to report that the Centre has had a successful and encouraging year. During the year the Society held eleven regular meetings in the University of Manitoba, all of which were well attended and seven of which were open to the public; the remaining four were for members and any friend whom the member might wish to invite as a guest.

Observation meetings were held under the leadership of Dr. Warren, Mr. A. W. Megget, Mr. D. R. P. Coats and Mr. G. P. Morse.

There were two meetings of the Council. We record with regret the death during the year of Mr. Gilbert Bartholomew, a member actively engaged in the work of the Society.

Ten new members were elected during the year, making our membership at the present time 69; and two resignations were received.

The following papers were given:

January 11—Prof. L. A. H. Warren, M.A.: The Redward Shift, Mr. A. R. McCauley, B.A.: Weather Facts and Fallacies.

January 25—Mr. D. R. P. Coats: Amateur Telescope Making.

February 8—Mr. A. V. Pigget, B.A.: Lessons from Orion and the Pleiades.

February 22—Prof. V. W. Jackson, M.A.: Equation of Time.

March 8—Mr. S. E. McColl: Surveys in Manitoba.

March 22—Mr. J. H. Kolb: Lunar Craters; Mrs. A. S. Willis: Antares in Scorpio; Mr. Howard Nicholls: Lunar Shadows; Mr. L. A. G. Lardner: Does the Earth Rotate?

April 12—Mr. D. R. P. Coats: The Sun and Radio Reception; Dr. Neil John Maclean: A Trip to the Dominion Observatory at Victoria; Mr. L. T. S. Norris-Elye: Speeds in Space; Mr. A. V. Thomas: The Conquest of Space.

October 11—Prof. L. A. H. Warren, M.A.: Fundamentals of Astronomy.

October 25—Mr. A. W. Megget: A short talk on the Glacial Period. This was followed by reports of summer observations.

November 8—Mr. D. R. P. Coats: Astronomy—What's the use?

December 13—Mr. A. W. Megget: Sights Worth Seeing.

J. C. HOWEY, *Secretary.*

FINANCIAL STATEMENTS FOR 1933

I. GENERAL TREASURER

GENERAL ACCOUNT

Receipts		Disbursements		
Bank balance, Dec. 31, 1932	$ 605.41	Publications		$1,973.79
Grants	2,450.00	Public meetings		62.30
Fees	1,397.50	Library		38.87
Publications	323.74	Discount		.39
Interest and exchange	112.40	Stationery and stamps		229.39
Stationery and stamps	15.35	Salary, Asst. Librarian		660.00
		Janitor		12.00
		Rent		120.00
		Grants:		
		Toronto	$144.00	
		Edmonton	48.00	
		Hamilton	73.50	
		London	71.00	
		Montreal	96.00	
		Ottawa	73.50	
		Vancouver	58.00	
		Victoria	92.50	
		Winnipeg	38.00	
				$ 694.50
		Miscellaneous		87.05
		Bank balance		1,026.11
	$4,904.40			$4,904.40

LIFE MEMBERSHIP ACCOUNT

Receipts		Disbursements	
Balance, Dec. 31, 1932	$ 80.34	Balance, a/c 4390	$199.31
Bank interest	3.47		
Bond interest	15.50		
New members, 4	100.00		
	$199.31		$199.31

BUILDING FUND ACCOUNT

Receipts		Disbursements	
Balance, Dec. 31, 1932	$260.24	Safety box	$ 2.00
Bank interest	7.97	Balance, a/c 4383	473.71
Bond interest	207.50		
	$475.71		$475.71

SOUTHAM PRESS FUND

Balance, Dec. 31, 1932, held in General Account 4359	$ 134.11
Bond interest	65.00
Total, held in General Account	199.11
Face value of bonds	1,300.00

LIST OF BONDS, HELD BY IMPERIAL BANK FOR SAFE-KEEPING

Description	Face	Maturity	Rate	Interest
Building Fund				
Dom. of Can. TE018682	$1,000.00	1934	5½%	$ 55.00
Dom. of Can. NE029210	1,000.00	1941	5%	50.00
Can. Perm. Mge. L15591	500.00	1935	5%	25.00
Can. Perm. Mge. L15592	500.00	1935	5%	25.00
Can. Perm. Mge. L13275	500.00	1936	5%	25.00
Can. Perm. Mge. L20932	500.00	1937	5½%	27.50
	$4,000.00			$207.50
Life Membership Fund				
Dom. of Can. R_2TA083071	$ 100.00	1943	5%	$ 5.00
Dom. of Can. R_2TA083072	100.00	1943	5%	5.00
Can. Perm. Mge. L20933	100.00	1937	5½%	5.50
	$ 300.00			$ 15.50
Southern Press Fund				
Dom. of Can. N_1A013817	$ 100.00	1936	5%	$ 5.00
Dom. of Can. N_1A013818	100.00	1936	5%	5.00
Dom. of Can. N_1A013819	100.00	1936	5%	5.00
N.S.L. N_2E008218	1,000.00	1941	5%	50.00
	$1,300.00			$ 65.00
Totals	$5,600.00			$288.00

(Signed) J. H. Horning, *General Treasurer.*

Audited and found correct,
January 8, 1934.

(Signed) J. E. Maybee, A. R. Hassard, *Auditors.*

II. STATEMENTS FOR THE CENTRES

1. TORONTO CENTRE

Receipts		Disbursements	
Balance, Jan. 1, 1933	$169.53	Rent	$ 58.50
Grant from Gen. Treas.	144.00	Rubber stamps	1.80
Refund of rent paid by Toronto Centre but due by General Council	8.00	Cash book	.45
		Treasurer, stamps	.83
		Gen. Treas., stamps, etc., used in sending notices of meetings and fees due	25.70
		Printing notices	13.07
		Advertising	17.95
		Balance to 1934	203.23
	$321.53		$321.53

(Signed) J. Edw. Maybee, *Treasurer.*

2. EDMONTON CENTRE

Receipts		Disbursements	
Balance from 1932	$ 2.57	Remitted to Gen. Treas.	$ 84.15
Membership fees (1933)	72.00	Postage and printing	6.70
Membership fees (1934)	12.00	Stationery	6.00
Grant from Gen. Treas.	48.00	Refreshments after meetings	12.00
Bank interest	1.63	Lecture expenses	4.00
		Balance on hand	23.35
	$136.20		$136.20

(Signed) E. H. Gowan, *Treasurer.*

(Signed) E. N. Higinbotham, *Auditor.*

3. HAMILTON CENTRE

Receipts		Disbursements	
Bank balance	$ 52.99	Printing and cards	$ 33.10
Membership fees	76.00	Lecture Hall	24.00
Grant from Gen. Treas.	45.50	Lecturers' expenses	6.00
Interest	1.05	Postage	1.15
Donations	11.39	Remitted to Gen. Treas.	91.00
		Lantern slides	17.50
		Bank balance	14.18
	$186.93		$186.93

4. LONDON CENTRE

Receipts		Disbursements	
Bank balance, Dec. 8, 1932	$ 59.21	Expenses of Annual Meeting	$ 5.85
Grant from Gen. Treas.	71.00	Honorarium (G. Fitchett, Normal School)	2.00
Fees for 1933	120.00	Honorarium (H. Billings, London Life Bldg.)	5.00
Bank interest	3.24	Flowers	2.00
		Picnic expenses	1.20
		Travelling expenses of lecturer	10.00
		Remitted to Gen. Treas.	120.00
		Exchange and postal note	.35
		Secretary's supplies	1.60
		Typing, stamps, etc.	13.81
		Bank balance, Dec. 7, 1933	91.64
	$253.45		$253.45

(Signed) N. Morris, *Treasurer.*

Audited and found correct,
December 8, 1933.

(Signed) E. H. Anundson, J. C. Higgins, *Auditors.*

5. MONTREAL CENTRE

Receipts		Disbursements	
Cash in bank and on hand, Oct. 15, 1932	$276.09	For purchase of telescope	$205.00
Members' fees, 85 at $2.00	170.00	Remitted to Gen. Treas.	170.00
Grant from Gen. Treas.	96.00	Lecturer's honorarium	30.00
Donation to General Fund	23.00	Lecturer's expenses	3.20
Donation for purchase of telescope	106.00	Typing and mimeographing	11.51
Interest on bank deposits	9.59	Expense *re* meetings (lantern, etc.)	15.00
		Postage	10.25
		Stationery	2.73
		Exchange on cheques	.68
		Balance on hand, Oct. 15, 1933	232.31
	$680.68		$680.68

(Signed) A. Vibert Douglas, *Treasurer.*

Audited and found correct,
November 2, 1933.

(Signed) O. A. Ferrier, *Certified Public Accountant.*

6. OTTAWA CENTRE

Receipts		Disbursements	
Bank balance, Dec. 20, 1932	$158.73	Remitted to Gen. Treas.	$147.00
Amount collected in dues	89.00	Printing and stationery	9.46
Grant from Gen. Treas.	73.50	Postage, exchange	12.61
Interest on deposits	2.30	Advertising	12.80
		Balance on hand	141.66
	$323.53		$323.53

Audited and found correct,
December 20, 1933.
(Signed) D. B. Nugent, *Auditor.*

(Signed) A. W. Grant, *Treasurer.*

7. VANCOUVER CENTRE

Receipts		Disbursements	
Balance from 1932	$ 15.56	Remitted to Gen. Treas.	$ 61.50
Fees for 1933	68.00	Bank exchange	.25
Fees for 1934	10.00	Printing and sec'y supplies	13.15
Grant from Gen. Treas.	58.00	Programmes	7.45
Bank interest	1.59	Notices of meetings	25.92
		Expenses:	
		Dr. Plaskett's visit	8.95
		Mr. Harper's visit	8.15
		Balance in bank	27.78
	$153.15		$153.15

Audited and found correct,
December 12, 1933.
(Signed) J. H. Bowman, C. A. McDonald, *Auditors.*

(Signed) J. L. Bennett, *Tresurer.*

8. VICTORIA CENTRE

Receipts		Disbursements	
Balance forward (per report of treasurer 1932)	$ 28.82	Sent to Toronto on account of dues collected in 1932 ($245.00)	$205.00
Dues received during 1933	175.00	Rent and janitor service	25.00
Voluntary contributions from members	21.00	Summer Lecture Course	5.75
Summer Lecture Course	15.50	Printing, stationery, etc.	48.92
Grant from Gen. Treas. (being one half of dues received in 1931)	92.50	Postage, express and telephone	19.36
Interest, etc.	.93	Sundries	4.25
		Balance on hand	25.47
	$333.75		$333.75

MEMORANDA

Due Toronto on account of dues collected in 1932 ($245.00)		$40.00
Cash on hand as above	$25.47	
Deficit	14.53	
		$40.00
Dues unpaid for 1932	2.00	
Dues unpaid for 1933	24.00	
		$26.00

(Signed) H. Boyd Brydon, *Secretary-Treasurer.*

Audited and found correct.

(Signed) W. T. Bridge, *Auditor.*

9. WINNIPEG CENTRE

RECEIPTS		DISBURSEMENTS	
Balance statement of 1932	$ 1.91	Advertising	$ 18.02
Grant from Gen. Treas.	38.00	Printing	18.00
Subscriptions:		Honorarium	6.50
Fees for 1931	2.00	Operation of lantern	12.00
Fees for 1932	14.00	Postage	9.82
Fees for 1933	62.00	Fees remitted to Gen. Treas.	76.00
Fees for 1933-34	2.50	Balance in bank, Dec. 13, 1933	.07
Fees for 1934 (advance)	10.00		
Fees for 1934-1938	10.00		
	$140.41		$140.41

(Signed) J. H. Kolb, *Treasurer.*

Certified correct.

(Signed) Una C. Taylor, James Houston, *Auditors.*

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

Observations of the 1933 Leonids—Part I

A program of photographic and visual observations of the Leonid meteors was carried out at a number of stations in and near Toronto on the nights of Nov. 14-15, 15-16, and 16-17, 1933. It is proposed this month to discuss those observations made at the David Dunlap Observatory and next month to report on the others.

The visual observations were organized on the same general plan as those of 1932 at the Harvard Observatory. Groups were made up of one recorder together with three to six observers. All meteors seen were plotted and recorded to the nearest second. Each group worked independently, covering a certain portion of the sky. Later, the records of the various groups were compared, all duplicate meteors picked out, and thus the total count for the whole party determined. Mr. K. O. Wright, of the Department of Astronomy at Toronto, took complete charge of the organization and the carrying out of the observations at the David Dunlap Observatory, the writer being located at the Harvard Observatory during the Leonid period. Mr. Wright also performed the above reduction, the chief difficulty encountered being uncertainties in timing owing to the fact that some of the timepieces did not function properly in the below-zero weather which greeted the observers. Observations were also made with a reticle similar to that described in *Popular Astronomy, 41*, 283, 1933.

The personnel of the Dunlap Observatory station is listed below:

Nov. 14-15

Recorders: Miss A. A. Crutcher, Mrs. P. M. Millman.
Observers: T. R. Jones, J. L. McCaul, T. J. Powell, C. B. Rigg, K. O. Wright.
Reticle: F. A. O. Banks, W. M. Gray, R. B. Laing, A. D. Misener.
Photography: R. D. Falconer.

Nov. 15-16

Recorders: F. A. O. Banks, G. Brown, G. E. Hay, Mrs. P. M. Millman, Miss F. S. Patterson, R. G. Romans.

Observers: Miss M. E. Carr, A. I. Cove, R. H. Craddock, Miss A. De Guerre, L. A. E. Doe, C. H. Dowker, Miss M. A. Eddy, J. H. Fee, Miss V. E. Foster, W. M. Gray, F. C. Hardy, J. N. D. Holden, Miss M. H. M. Hunt, Miss M. F. James, R. J. James, N. V. Jefferson, T. R. Jones, D. Kilgour, J. R. Levitt, M. R. Macphail, Miss M. I. McKerrall, N. McMillen, A. A. P. Menzies, D. C. Murdock, Miss L. H. Newton, Miss R. I. Northcott, T. J. Powell, C. B. Rigg, J. M. Speirs, Miss M. J. Thomson, Miss H. C. White, W. C. Wilson.
Reticle: C. C. Boughner, C. R. A. Day, R. B. Laing, F. G. Millar.
Photography: A. D. Misener, G. F. Smith, K. O. Wright.

Nov. 16-17

Recorder: Mrs. P. M. Millman.
Observers: Miss V. E. Foster, T. R. Jones, Miss L. E. Pallett, Miss F. S. Patterson, Miss M. J. Thomson.
Reticle: W. M. Gray.
Photography: K. O. Wright.

The nights of Nov. 14-15 and 15-16 were clear and cold. Nov. 16-17 started to cloud in shortly after midnight and after alternate clearing and clouding till 3 a.m. the sky clouded up for the rest of the night. For that reason no estimate of the total number of meteors appearing on Nov. 16-17 can be obtained from the Toronto observations. The total number of meteors observed by the whole party is given in Table I. These numbers contain no duplicate meteors.

Of these meteors 630 were plotted on the maps. Since the number of observers varied throughout the night it was thought best to reduce the above counts to a standard of six observers and this was done by multiplying the actual count for each twenty-minute interval by the factors in Table II. These factors depend on the number of observers and were formed from an average of tables given by Denning, (*Obs.*, *20*, 373, 1897), and Kleiber, (*A.N.*, *110*, 69, 1884). Denning concluded that six observers will see half the meteors visible.

The reduced rates for the first two nights are shown in the diagram, each plot being for the thirty minutes preceding and following. The steady increase of the Leonid rate to a maximum is very noticeable on both nights. This maximum rate occurred about 4.25 a.m. on Nov. 15 and at 4.15 a.m. on Nov. 16. In the

TABLE I

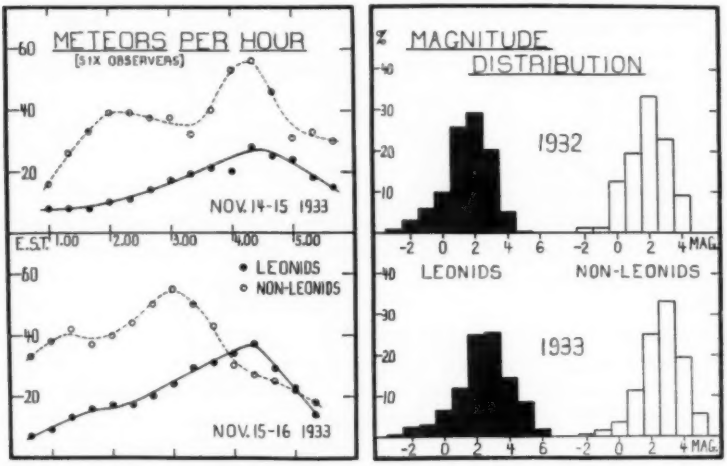
E.S.T.	Nov. 14-15		Nov. 15-16		Nov. 16-17	
	Leonids	Non-Leonids	Leonids	Non-Leonids	Leonids	Non-Leonids
12.30–12.50	0 *	3	3	12	0 *	1
12.50– 1.10	5	5	6	30	2	2
1.10– 1.30	2	6	7	21	3	8
1.30– 1.50	1	12	8	16	1 *	2
1.50– 2.10	4	10	8	16		
2.10– 2.30	4	11	7	25		
2.30– 2.50	2	12	9	24	0 *	4
2.50– 3.10	4	6	15	28	0 *	2
3.10– 3.30	5	8	16	36		
3.30– 3.50	3	6	15	17		
3.50– 4.10	7	13	14	13		
4.10– 4.30	4	17	18	12		
4.30– 4.50	8	8	23	15		
4.50– 5.10	5	6	5	12		
5.10– 5.30	4	8	6 *	4		
5.30– 5.50	6	15				
5.50– 6.10	1 *	1				
Totals	65	147	160	281	6	19

Total Leonids observed 231.
Total Non-Leonids observed 447. Total meteors observed 678.
*Incomplete periods.

TABLE II

Observers	Factor	Observers	Factor	Observers	Factor	Observers	Factor
1	3.5	9	.86	17	.67	25	.56
2	1.91	10	.83	18	.65	26	.55
3	1.45	11	.80	19	.63	27	.54
4	1.22	12	.77	20	.61	28	.53
5	1.09	13	.75	21	.60	29	.53
6	1.00	14	.73	22	.59	30	.52
7	.93	15	.71	23	.58	31	.51
8	.89	16	.69	24	.57	32	.50

1932 observations at Harvard the maximum rate on Nov. 16 was at 3.55 a.m. The corresponding local mean times are 4.08, 3.58, and 4.09 respectively, showing very good agreement. The Non-Leonids were surprisingly numerous in 1933, many seeming to come from radiants to the west of the Leonid radiant. Their varying hourly rate throughout the night is in marked contrast to the behaviour of the Leonids. The six brightest meteors on the morning of Nov. 17 were all Non-Leonids with an average magnitude brighter than −1. Two daylight meteors were ob-



served on Nov. 15, shortly before sunrise, as the party was leaving the observatory. These meteors appeared within thirty seconds of each other and were apparently Leonids, leaving trains that remained visible for several seconds.

A study of the magnitude estimates is of great interest, especially when these are compared with those made at the Harvard stations in 1932. These estimates were made by comparing the meteors with stars of known magnitude that were in the field of view. The magnitude distributions of 486 meteors observed on Nov. 15 and 16, 1932, and of 489 meteors observed on the same dates in 1933 are given in Table III.

TABLE III

Mag.	−6	−3	−2	−1	0	1	2	3	4	5	6	Totals	Mean Mag.
Harvard (1932)													
Leonids.....	1	2	12	23	39	103	117	81	20	1		399	1.53
Non-Leonids			1	1	11	17	29	20	8			87	1.89
Toronto (1933)													
Leonids.....		1	4	5	11	20	42	43	24	14	3	167	2.40
Non-Leonids			1	5	11	36	81	107	63	18		322	2.66

These magnitude distributions are plotted in percentages in the diagram. The effect of the moon, which on Nov. 15, 1932, was two days past the full, is clearly evident in the brighter mean magnitudes for that year. The effect of the moon in cutting down the number of meteors visible appears first for meteors of the second magnitude. The mean magnitude of the Non-Leonids differs from the Leonids by a small but definite amount, averaging 0.3 magnitudes. If N_m represents the number of meteors of magnitude m we find that for Leonids for magnitudes −3 to 2

$$\frac{N_{m+1}}{N_m} = 2.25 \pm .15$$

Similarly for Non-Leonids from magnitudes −2 to 2

$$\frac{N_{m+1}}{N_m} = 2.60 \pm .20$$

These values agree in the mean with those previously determined by Opik and others. If these ratios hold for fainter magnitudes then only about one-half the 3rd. magnitude meteors will be observed on moonless nights and one-sixth on nights when there is a bright moon. The corresponding values for the 4th. magnitude meteors are one-tenth and one-fiftieth.

By making use of the magnitude distributions it is possible to allow for the presence of the moon in 1932 and to compare the relative numbers of Leonids appearing during the last two years from the counts made at Harvard in 1932 and at Toronto in 1933.

Both programs were carried out in the same way and the reductions were identical. We find that the ratio of the number of Leonids in 1933 to the number in 1932 is nine-tenths for the morning of Nov. 15 and one-quarter for Nov. 16. The Non-Leonids, on the other hand, were three times as numerous on Nov. 15, 1933, and twice as numerous on Nov. 16, 1933, as in the previous year.

In addition to the meteors reported above, 23 were observed with the reticle on Nov. 15 and 29 on Nov. 16. Most of these were also observed by the other groups and appear in the total counts.

Two spectrographs and two direct cameras were in operation on all three nights. Eastman I. C. Special infra red plates were used on one of the spectrographs, Imperial and Gevaert Orthos on the other cameras. Some trouble was experienced with frost on the lenses and prisms. No meteor spectra were photographed in the 6.8 hours total exposure made with the spectrographs. Total exposures of 12.0 hours were made with direct cameras, the lenses being of the type used for auroral photography with aperture ratios of 1.25. A zero magnitude meteor was photographed on Nov. 15 and a second magnitude meteor on Nov. 16. Both of these were Non-Leonids.

In conclusion I would like to express my sincere thanks to all those who contributed to making the Leonid program a success despite extremely adverse weather conditions and an unexpectedly poor showing of meteors.

P.M.M.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

THE LOS ANGELES PLANETARIUM.

In a note in the issue for last month (p. 88) the interesting news was given that the American Museum of National History was to have a Zeiss planetarium, and it was stated that it would be the third in the United States. The present writer was aware that a planetarium for the city of Los Angeles had been under consideration, but as no information had been forthcoming recently regarding it, the presumption was that the financial depression had caused it to be postponed. It is a great pleasure to learn that this is a mistake, and that, following the old adage, no news was good news. Mr. Ferdinald Ellerman of the Mount Wilson Observatory informs me that the planetarium is being built on a site in the hills to the north of the city, that the building is nearing completion and the various supplementary exhibits are being collected. He also reports with regret that Dr. Edgar H. Kurth, who has been actively engaged in carrying the project forward, was, a short time ago, killed by a speeding automobile. Dr. Kurth had designed the best display rooms and had secured many fine astronomical exhibits, instruments, photographs, etc. Whatever the order of priority in establishing the planetariums, cities which they serve are to be congratulated.

THE SMITHSONIAN ASTROPHYSICAL OBSERVATORY.

The Astrophysical Observatory of the Smithsonian Institution steadily continues its quite unobtrusive but very valuable work, as its report for 1933 shows. Its chief object is the measurement of the solar constant of radiation and the discussion of its relation to terrestrial conditions. Director C. G. Abbott thus summarises the work done:

> Valuable progress has been made on the study of the dependence of terrestrial temperature departures on the variation of the sun. Interesting studies have begun on the dependence of terrestrial temperature departures on the ozone content of the atmosphere; solar-radiation observations have been continued at Table Mountain, Calif., Montezuma, Chile, and the co-operating private station at Mount St. Katherine in Sinai Peninsula is being equipped.

A new radiation measuring instrument of highest sensitiveness called the kampometer has been devised and used with success in preliminary measurements of the extreme infra-red solar spectrum.

Ball Lighting—Three Discharges.

The phenomenon of ball lightning is still so much of a mystery that it is advisable to secure all possible observations upon it, and our readers will be interested to read the account of three discharges given in *Nature* of February 3, 1934, by Marshall Holmes. It runs as follows:

At 4.15 p.m. on January 11, the phenomenon of ball lightning occurred at the house of Mr. Joseph M. Wreath, Ballymoney, Co. Antrim.

A first ball exploded against the corner of a metal-bound tea chest just inside the wide open door of a coach-house. A second exploded a minute or two later against a ladder leaning against the same coach-house. A third entered a ground floor room of the dwelling-house, having come down the chimney against the up draught due to a fire burning at the time. It exploded in the fireplace.

The balls outside were seen by Mr. Wreath and a friend, who describe them as orange-red and as being of about the size and having the velocity of a cricket ball. That indoors was seen by two ladies.

A wireless aerial is attached to the chimney stack by which the third ball entered the dwelling-house.

Eclipse of the Sun, February 13-14.

The path of totality of this eclipse began near Java and ended off the coast of British Columbia and thus the eclipse began on one day and ended on the day before.

Expeditions from the United States and Japan went to the island of Losap and report a clear sky about the sun at the time of the total phase. The corona was of the minimum sun-spot type.

C.A.C.

The Royal Astronomical Society of Canada

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